IMAGE DISPLAY DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to an image display device, and in particular to an image display device, such as a monitor, which can display color images, and which permits a user to adjust the color reproducibility.

A prior art method of adjusting the color reproducibility for an image display device is described with reference to Fig. 19.

Fig. 19 shows an example of control panel for adjusting the color reproducibility in the prior art image display device. In Fig. 19, reference numeral 101 denotes a red signal intensity setting means, 102 denotes a green signal intensity setting means, and 103 denotes a blue signal intensity setting means. In Fig. 19, the signal intensities of red, green and blue are adjusted using the red signal intensity setting means 101, the green signal intensity setting means 102 and the blue signal intensity setting means 103. For example, if the signal intensities of green and blue are reduced, the image displayed will generally be reddish.

In the image display device provided with the above-described adjusting means, it is only possible to adjust the signal intensities of red, green and blue, with respect to all the colors in the image, and it is not possible to finely adjust the colors according to the preference of the user. For instance, with the image display device provided with the above-described adjusting means, it is not possible to adjust only a specific color. Moreover, it is not possible to adjust the chroma of the color.

Japanese Patent Kokai Publication H05-48885 discloses a different method of adjusting the color image. According to the method disclosed in Japanese Patent Kokai Publication

No. H05-48885, an image is displayed on an image display device, simulating an image outputted from a hard copy device. While observing the simulation image displayed on the image display device, the optimum parameters for the hard copy device are determined. The concept of the image adjustment for the hard copy device can be applied to an image display device.

Fig. 20 shows the configuration of a device using the image adjustment method disclosed in Japanese Patent Kokai Publication No. H05-48885. In Fig. 20, reference numeral 104 denotes a keyboard, 105 denotes a mouse, 106 denotes an input means, 107 denotes a controller, 108 denotes an input circuit, 109 denotes a memory, 110 denotes a CPU, 111 denotes an output circuit, 112 denotes an image display unit, 113 denotes an original image, 114 denotes a processed image, 115 denotes set parameters, and 116 denotes a hard copy device. The keyboard 104 and the mouse 105 are both an example of the input means 106. The controller 107 is formed of the input circuit 108 connected to the input means 106, the memory 109, the CPU 110, and the output circuit 111. The image display unit 112 is driven by the output circuit 111. The operation of the device using the image adjustment method of Fig. 20 will next be described.

The memory 109 stores a color conversion simulation program. The CPU 110 executes the program stored in the memory 109. First, it reads the image data used for the color conversion simulation. The image data having been read is displayed as the original image 113 on the image display unit 112. Next, the input means 106 is used to input the specific manner of processing specifying how the processing is to be performed. Then, the color conversion performed by the hard copy device 116 is simulated, on the image data having been read, in accordance with the designated manner of processing. The color converted,

processed image 114 is displayed on the screen of the image display device 112, together with the original image 113. When the parameters for the color conversion can be changed step-wise, a plurality of the processed images which are obtained from the respective steps are displayed together, arranged in an array. By selecting that one of the processed images that is closest to the original image 113, the optimum parameters are determined. For determining a plurality of parameters, the above-mentioned operations are repeated, so that the parameters are determined in turn. The color conversion parameters thus determined are sent to the hard copy device.

In the device using the above-described image adjustment method, the color conversion is simulated in accordance specific manner of processing designated by the input means 106, and by selecting that one of the processed images which is optimum, the color conversion parameters can be determined. Accordingly, there ia a freedom in the adjustment depending on the type of the color conversion parameters that can be set. The freedom in the adjustment is greater than in the arrangement in which adjustment is made only on the signal intensities of red, green and blue. Moreover, it is easy for the user to set the parameters.

The above-described color adjustment method has a problem in that because simulation is performed by means of a CPU, if the accuracy of the simulation is low, the parameters that are determined are not necessarily optimum. Moreover, the load on the CPU which performs the simulation is heavy. Furthermore, because the simulation by means of the CPU is used, it is not suitable for a real-time processing of moving pictures due to the limitation in the processing speed.

When a plurality of processed images are displayed simultaneously, it is necessary to perform the simulation a

number of times equal to the number of processed images displayed simultaneously, so that the problems of the load on the CPU and the processing speed are more serious. In addition, when a plurality of processed images are displayed simultaneously, the size of each of the displayed processed images is small, so that they may give different impression than the image outputted at full size, after the determination of the parameters.

SUMMARY OF THE INVENTION

The invention has been made to solve the problems described above.

An object of the invention is to provide an image display device with which the user can adjust the chroma, which can perform real-time processing of moving pictures, and the images after the adjustment can be displayed at full size.

According to a first aspect of the invention, there is provided an image display device for receiving an input image data comprising three or more color data, and displaying the input image data on an image display unit, comprising:

a color converter for converting a first image data comprising three or more color data, into a second image data comprising three or more color data, on the basis of conversion characteristics data;

a conversion characteristics storage for storing the conversion characteristics data;

conversion characteristics designation means for designating conversion characteristics to be used by the color converter, and outputting conversion characteristics designation data; and

conversion characteristics setting means for calculating the conversion characteristics data on the basis

of the conversion characteristics designation data, and setting the conversion characteristics data in the conversion characteristics storage;

wherein

said conversion characteristics designation means comprises:

chroma designation means for designating the chroma of the color represented by the second image data comprising three or more colors;

said color converter comprises:

a calculation term generator for receiving the first image data, and outputting calculation terms which are effective just for the specific hues; and

a matrix calculator for calculating the second image data, said matrix calculator performing calculation including matrix calculation using said calculation terms effective just for the specific hues.

With the above arrangement, the user can designate the conversion characteristics by the use of the conversion characteristics designation means. Moreover, where the colors for which the conversion characteristics can be designated by the use of the conversion characteristics designation means and the hues for which the calculation terms generated in the color converter are effective correspond with each other, the calculation of the conversion characteristics data is easy. Moreover, since the color converter performing the color conversion is formed of hardware, a real-time processing of moving pictures can be achieved without placing a heavy load on a CPU. Furthermore, the image data obtained by the color conversion are sent (e.g., via image data output circuit) to the image display unit, the image after the adjustment is displayed on the image display unit with a size equal as the image before the adjustment, so that the user can designate

the conversion characteristics while observing the result of the adjustment.

It may be so arranged that

said conversion characteristics data includes matrix calculation coefficients used in said matrix calculator; and

said conversion characteristics setting means calculates the conversion characteristics data by adding or subtracting the values corresponding to the values of the conversion characteristics designation data to or from the coefficients among the coefficients for the calculation terms effective just for the specific hues.

With the above arrangement, the calculation of the conversion characteristics is easy.

It may be so arranged that

said chroma designation means designates the chroma of the colors represented by the second image data, by designating its ratio to the chroma of the colors represented by the first image data.

With the above arrangement, the user can adjust the chroma easily.

It may be so arranged that said first image data include three color data of red, green and blue.

With the above arrangement, the user can designate the conversion characteristics by the use of the conversion characteristics designation means, for the image data including the three color data of red, green and blue.

It may be so arranged that

the chroma designation means comprises:

means for selecting the color for which the chroma is designated; and

means for designating the chroma for the selected color.

With the above arrangement, the user can adjust only such a color that the user wishes to adjust, by designating

the conversion characteristics of the color for which it is desired to make adjustment by the use of the conversion characteristics designation means.

It may be so arranged that said colors for which the chroma is designated includes three colors of red, green and blue.

With the above arrangement, it is possible to adjust only such a color for which adjustment is desired, among the three colors of red, green and blue.

It may be so arranged that said colors for which the chroma is designated includes six colors of red, green, blue, yellow, magenta and cyan.

With the above arrangement, it is possible to adjust only such a color for which adjustment is desired, among the six colors of red, green, blue, yellow, magenta and cyan.

It may be so arranged that said conversion characteristics designation data include

information indicating the color that has been selected by the chroma designation means; and

information indicating the chroma designated for the selected color.

With the above arrangement, generation of the conversion characteristics data at the conversion characteristics designation means is easy.

It may be so arranged that said calculation term generator comprises:

color extracting means for extracting chromatic and achromatic components from the first image data; and

a polynomial calculator performing comparison operation on the chromatic components.

With the above arrangement, generation of calculation terms effective just for specific hues is easy.

It may be so arranged that

said color extracting means comprises:

a minimum and maximum calculator for calculating a minimum value α and a maximum value β of said first image data; and

a hue data calculator for calculating hue data r, g, b, y, m and c based on said first image data, and said minimum and maximum values α and β outputted from said minimum and maximum calculator;

said polynomial calculator comprises:

means for generating first comparison-result data based on the hue data (r, g, b, y, m, c) outputted from said hue data calculator; and

means for generating second comparison-result data based on said first comparison-result data; and

said matrix calculator is responsive to said hue data, said first comparison-result data, said second comparison-result data, and said minimum value, and performs said matrix calculation using at least said first comparison-result data, said second comparison-result data, and said hue data, and in accordance with the conversion characteristics data from the conversion characteristics storage.

With the above arrangement, it is possible to independently vary not only the colors of the six hues of red, blue, green, yellow, cyan and magenta, but also the colors in the six inter-hue areas of red-yellow, yellow-green, green-cyan, cyan-blue, blue-magenta, and magenta-red, by independently setting the coefficients relating to the target hue or inter-hue area.

It may be so arranged that

said first image data include three color data of red, green and blue,

said minimum and maximum calculator determines the minimum and maximum of the three color data R, G and B;

said hue data calculator calculates the hue data r, g,

b, y, m, c by subtraction in accordance with:

$r = R - \alpha$,

$g = G - \alpha$,

$b = B - \alpha$.

$y = \beta - B$,

$m = \beta - G$, and

$c = \beta - R$;

said first comparison-result generator generate the first comparison-result data between the hue data r, g, b and y, m, c;

said second comparison-result generator comprises:

multiplying means for multiplying predetermined coefficients with said first comparison-result data; and

means for producing the second-comparison result data using the outputs of the multiplying means.

With the above arrangement, the hue data can be calculated from the input image data R, G and B, and the minimum and maximum value, and the first comparison-result data and the second comparison-result data can be produced by simple operations such as comparison, addition, subtraction, and multiplication.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:-

Fig. 1 is a block diagram showing an example of configuration of an image display device of Embodiment 1;

Fig. 2 shows an example of menus displayed on the screen of the image display device;

Fig. 3 shows an example of configuration of conversion characteristics designation data used for the image display device of Embodiment 1;

Fig. 4. is a block diagram showing an example of configuration of a color converter in the image display device of Embodiment 1;

Fig. 5 is a block diagram showing an example of configuration of a polynomial calculator in the color converter in the image display device of Embodiment 1;

Fig. 6 is a table showing an example of the relationship between an identification code S1, and the maximum and minimum values β and α, and hue data whose value is zero, in the color converter in the image display device of Embodiment 1;

Fig. 7 is a table showing the operation of a zero remover of the polynomial calculator in the color converter in the image display device of Embodiment 1;

Fig. 8 is a block diagram showing an example of configuration of a matrix calculator in the color converter in the image display device device of Embodiment 1;

Fig. 9A to Fig. 9F are diagrams schematically showing the relationship between six hues and hue data;

Fig. 10A to Fig. 10F are diagrams schematically showing the relationship between six hues and first comparison-result data in the color conversion device of Embodiment 1;

Fig. 11A to Fig. 11F are diagrams schematically showing the relationship between six inter-hue areas and second comparison-result data in the color converter in the image display device of Embodiment 1;

Fig. 12A to Fig. 12F are diagrams schematically showing how the range of each inter-hue area is changed with the change of the coefficients multiplied at the polynomial calculator is changed;

Fig. 13A and Fig. 13B are tables showing the relationship between respective hues or inter-hue areas, and effective calculation terms or data which relate to and are effective for each hue or inter-hue area;

Fig. 14 is a block diagram showing an example of configuration of conversion characteristics designation means in the image display device of Embodiment 1;

Fig. 15 is a block diagram showing an example of configuration of conversion characteristics designation means in the image display device of Embodiment 2;

Fig. 16 shows an example of menu displayed on the screen of the image display unit in the image display device of Embodiment 3;

Fig. 17 shows an example of configuration of the conversion characteristics designation data in the image display device of Embodiment 3;

Fig. 18 shows an example of menu displayed on the screen of the image display unit in the image display device of Embodiment 4;

Fig. 19 shows an example of adjustment section for adjusting the color reproducibility in the image display device in the prior art; and

Fig. 20 shows a configuration of the device using the image adjustment method in the image display device in the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will now be described with reference to the drawings.

Embodiment 1

Fig. 1 is a block diagram showing an example of configuration of an image display device of this embodiment. In the drawing, reference numeral 31 denotes an image data input circuit, 32 denotes a color converter, 33 denotes an image data output circuit, 34 denotes an image display device, 35 denotes a conversion characteristics storage, 36 denotes a conversion characteristics setting means and 37 denotes a conversion characteristics designation means.

The operations of the image display device shown in Fig. 1 will next be described. Image data Ri1, Gi1 and Bi1 comprising three color data are inputted to the image data

input circuit 31. The image data input circuit 31 performs input image processing on the inputted image data, to produce image data Ri, Gi and Bi comprising three color data. The input image processing performed at the image data input circuit 31 may be conversion of the number of pixels, or tone correction, according to the characteristics of the input image data. The image data Ri, Gi and Bi outputted from the image data input circuit 31 are inputted to the color converter 32. The color converter 32 performs color conversion on the inputted or first image data (input or first set of three color data) Ri, Gi and Bi, using the color characteristics data stored in the conversion characteristics storage 35, to produce another or second image data (output or second set of three color data) Ro, Go and Bo.

The second image data Ro, Go and Bo outputted from the color converter 32 are input to the image data output circuit 33. The image data output circuit 33 performs output image processing on the image data Ro, Go and Bo to produce image data Ro1, Go1 and Bo1, which are sent to the image display unit 34, which displays an image. The output image processing may be conversion of data format, or tone correction according to the characteristics of the image display unit 34.

The image display unit 34 may for example be a liquid crystal panel display device, or a CRT (cathode ray tube) display device.

The user can designate the desired conversion characteristics using the conversion characteristics designation means 37. The conversion characteristics designation means 37 generates conversion characteristics designation data in compliance with the designation by the user. The conversion characteristics designation data from the conversion characteristics designation means 37 is input

to the conversion characteristics setting means 36.

The conversion characteristics setting means 36 calculates the conversion characteristics data from the input conversion characteristics designation data, and sets the conversion characteristics data in the conversion characteristics storage 35.

The conversion characteristics designation means 37 can be implemented by menus displayed on the screen of the image display unit 34 and keys provided on the image display unit 34. In this case, the user can designate the desired conversion characteristics by selecting the options in the menus displayed on the screen of the image display unit 34, by means of the keys. Alternatively, the conversion characteristics designation means 37 may be implemented by a dedicated control panel, or the input devices such as a mouse and a key board. Here, it is assumed that the conversion characteristics designation means 37 is formed of menus displayed on the screen of the image display unit 34 and the keys provided on the image display unit 34.

Fig. 2 shows an example of menu displayed on the screen of the image display unit 34.

In Fig. 2, reference numeral 38 denotes a red chroma adjustment bar, 39 denotes a yellow chroma adjustment bar, 40 denotes a green chroma adjustment bar, 41 denotes a cyan chroma adjustment bar, 42 denotes a blue chroma adjustment bar, and 43 denotes a magenta chroma adjustment bar.

By using the keys provided on the image display unit 34, the user selects one of the red chroma adjustment bar 38, yellow chroma adjustment bar 39, green chroma adjustment bar 40, cyan chroma adjustment bar 41, blue chroma adjustment bar 42, and magenta chroma adjustment bar 43 that corresponds to the color for which the chroma is to be adjusted, i.e., the conversion characteristics is to be changed. The selected chroma adjustment bar lets the user

know that it has been selected, by varying its hue or brightness. When the selection of the desired chroma adjustment bar is completed, the user then designates the chroma of the selected color. The designation of the chroma is performed by designating the ratio of the chroma of each of the colors represented by the three color data Ro, Go and Bo (second set of three color data) outputted from the color converter 32, with respect to the chroma of each of the colors represented by the three color data Ri, Gi and Bi (first set of three color data) inputted to the color converter. This ratio may also be called a "multiplication factor. By repeating the above-outlined operation, the user can designate the desired color conversion characteristics. In the example of Fig. 2, the designated conversion characteristics is such that the chroma of each of red and cyan is to be multiplied by "1.1," the chroma of yellow is to be multiplied by "0.9," and the chroma of each of green, blue and magenta is multiplied by "1.0."

The conversion characteristics designation means 37 generates the conversion characteristics designation data in accordance with the values of the red chroma adjustment bar 38, yellow chroma adjustment bar 39, green chroma adjustment bar 40, cyan chroma adjustment bar 41, blue chroma adjustment bar 42 and magenta chroma adjustment bar 43. Fig. 3 shows an example of configuration of the conversion characteristics designation data. In the example shown in Fig. 3, the conversion characteristics designation data comprises red designation data (RED D. D.), yellow designation data (YELLOW D. D.), green designation data (GREEN D. D.), cyan designation data (CYAN D. D.), blue designation data (BLUE D. D.) and magenta designation data (MAGENTA D. D.) which are 1arranged in the stated order. The value of each of the designation data is the ratio of the chroma of each of the colors represented by Ro, Go and

Bo to the chroma of each of the colors represented by Ri, Gi and Bi, that has been designated by the user by the use of the chroma adjustment bar. With respect to the colors that are not adjusted by the user, the value of each designation data is "1.0." When the designation is as shown in Fig. 2, the red designation data is "1.1," the yellow designation data is "0.9," the green designation data is "1.0," the cyan designation data is "1.1," the blue designation data is "1.0," and the magenta designation data is "1.0."

The conversion characteristics setting means 36 calculates the conversion characteristics data on the basis of the conversion characteristics designation data from the conversion characteristics designation means 37, and sets them in the conversion characteristics storage 35. The conversion characteristics data is referred to by the color converter 32 when it performs the color conversion. When the color converter 32 is configured as a color converter of the matrix calculation type, the conversion characteristics data include coefficient used in the matrix calculation.

Fig. 4 is a block diagram showing an example of the configuration of the color converter 32. The illustrated color converter is for converting the first image data (the first set of three color data) representing red, green and blue, denoted by Ri, Gi and Bi, into the second image data (second set of three color data), also representing red, green and blue, denoted by Ro, Go and Bo. A minimum and maximum calculator 1 calculates a maximum value β and a minimum value α of the inputted image data Ri, Gi and Bi, and generates and outputs an identification code S1 for indicating, among the six hue data, data which are zero, as will be better understood from the following description. A hue data calculator 2 calculates hue data r, g, b, y, m and c from the image data Ri, Gi and Bi and the outputs from the minimum and maximum calculator 1. The color converter

further comprises a polynomial calculator 3, a matrix calculator 4, a coefficient generator 5, and a synthesizer 6.

The matrix calculator 4 is of the matrix calculation type, and the conversion characteristics data inputted to the coefficient generator 5 include calculation coefficients for the matrix calculation.

Fig. 5 is a block diagram showing an example of configuration of the polynomial calculator 3. In Fig. 5, a zero remover 7 removes, from the inputted hue data, data which are of value zero. Minimum selectors 9a, 9b and 9c select and output the minimum of the input data. A calculation coefficient selector 11 selects from among the coefficients generated by the coefficient generator 5, and outputs the selected coefficients as calculation coefficients based on the identification code S1 from the minimum and maximum calculator 1.

The selector 11 receives the signals aq1 to aq6, and ap1 to ap6, and selects one of aq1 to aq6, and one of ap1 to ap6, in accordance with the value of S1. The relationship between the selected ones of aq1 to aq6 and ap1 to ap6, and the value of S1 is as follows:

S1	aq	ap
0	aq1	ap1
1	aq2	ap2
2	aq3	ap3
3	aq4	ap4
4	aq5	ap5
5	aq6	ap6

The selector 11 having the function described above can be formed of logic circuits.

Arithmetic units 10a and 10b perform multiplication between the calculation coefficients represented by the outputs of the calculation coefficient selector 11 and the

outputs from the minimum selectors 9a and 9b.

Next, the operation will be described. The inputted image data Ri, Gi and Bi corresponding to the three colors of red, green and blue are sent to the minimum and maximum calculator 1 and the hue data calculator 2. The minimum and maximum calculator 1 calculates and outputs a maximum value β and a minimum value α of the inputted image data Ri, Gi and Bi, and also generates and outputs an identification code S1 for indicating, among the six hue data, data data which are zero.

The hue data calculator 2 receives the inputted image data Ri, Gi and Bi and the maximum and minimum values β and α from the minimum and maximum calculator 1, performs subtraction of

$r = Ri - \alpha$,

$g = Gi - \alpha$,

$b = Bi - \alpha$,

$y = \beta - Bi$,

$m = \beta - Gi$, and

$c = \beta - Ri$,

and outputs six hue data r, g, b, y, m and c thus obtained.

The maximum and minimum values β and α calculated by the minimum and maximum calculator 1 are respectively represented as follows:

$\beta = MAX (Ri, Gi, Bi)$

$\alpha = MIN (Ri, Gi, Bi)$

Since the six hue data r, g, b, y, m and c calculated by the hue data calculator 2 are obtained by the subtraction of

$r = Ri - \alpha$,

$g = Gi - \alpha$,

$b = Bi - \alpha$,

$y = \beta - Bi$,

$m = \beta - Gi$, and

$c = \beta - Ri$,

at least two among these six hue data are of a value zero. For example, if a maximum value β is Ri and a minimum value α is Gi (β = Ri, and α = Gi), g = 0 and c = 0. If a maximum value β is Ri and a minimum value α is Bi (β = Ri, and α = Bi), b = 0 and c = 0. In other words, in accordance with a combination of Ri, Gi and Bi which are the largest and the smallest, respectively, one of r, g and b, and one of y, m and c, i. e., in total two of them have a value zero.

Thus, in the foregoing minimum and maximum calculator 1, the identification code S1 for indicating, among the six hue data which are zero are generated and outputted. The identification code S1 can assume one of the six values, depending on which of Ri, Gi and Bi are of the maximum and minimum values β and α. Fig. 6 shows a relationship between the values of the identification code S1 and the maximum and minimum values β and α of Ri, Gi and Bi and hue data which has a value zero. In the drawing, the values of the identification code S1 represent just an example, and the values may be other than those shown in the drawing.

Then, the six hue data r, g, b, y, m and c outputted from the hue data calculator 2 are sent to the polynomial calculator 3, and the hue data r, g and b are also sent to the matrix calculator 4. The polynomial calculator 3 also receives the identification code S1 outputted from the minimum and maximum calculator 1, and performs calculation by selecting, from the hue data r, g and b, two data Q1 and Q2 which are not of a value zero, and from the hue data y, m and c, two data P1 and P2 which are not of a value zero. Next, this operation will be described by referring to Fig. 5.

The hue data from the hue data calculator 2 and the identification code S1 from the minimum and maximum calculator 1 are inputted to the zero remover 7 in the

polynomial calculator 3. The zero remover 7 outputs, based on the identification code S1, the two data Q1 and Q2 which are not of a value zero, among the hue data r, g and b and the two data P1 and P2 which are not of a value zero, among the hue data y, m and c. For instance, Q1, Q2, P1 and P2 are determined as shown in Fig. 7, and then outputted. If, for example, the identification code S1 is of a value zero, Q1 and Q2 are obtained from the hue data r and b, and P1 and P2 are obtained from the hue data y and m, so the outputs are given by Q1 = r, Q2 = b, P1 = m and P2 = y. As in the case of Fig. 6, the values of the identification code S1 in Fig. 7 represent just an example, and may be other than those shown in Fig. 7.

The minimum selector 9a selects and outputs the minimum value T4 = min (Q1, Q2) among the output data Q1 and Q2 from the zero remover 7. The minimum selector 9b selects and outputs the minimum value T2 = min (P1, P2) among the output data P1 and P2 from the zero remover 7. The outputs of the minimum selectors 9a and 9b are the first comparison-result data.

The identification code S1 is inputted from the minimum and maximum calculator 1 to the calculation coefficient selector 11, which selects signals indicating calculation coefficients aq and ap from among the signals generated by the coefficient generator 5, the selection being made based on the identification code S1, and the coefficient aq is supplied to the arithmetic unit 10a, and the coefficient ap is supplied to the arithmetic unit 10b. These calculation coefficients aq and ap are used for multiplication with the comparison-result data T4 and T2, and each of the calculation coefficients aq and ap can assume one of the six values, corresponding to the value of the identification code S1 shown in Fig. 7.

The arithmetic unit 10a receives the comparison-result

data T4 from the minimum selector 9a, performs multiplication of aq*T4, and sends the result to the minimum selector 9c. The arithmetic unit 10b receives the comparison-result data T2 from the minimum selector 7, performs multiplication of ap*T2, and sends the result to the minimum selector 9c.

The minimum selector 9c selects and outputs the minimum value T5 = min (aq*T2, ap*T4) of the outputs the arithmetic units 10a and 10b. The output of the minimum value selector 9c is a second comparison-result data.

The polynomial data T2, T4 and T5 outputted from the polynomial calculator 3 are supplied to the matrix calculator 4.

The coefficient generator 5 shown in Fig. 4 selects the calculation coefficients U(Fij) and the fixed coefficients U(Eij) for the polynomial data, from among the conversion characteristics data stored in the conversion characteristics storage 35, in accordance with the identification code S1, and outputs the selected coefficients to the matrix calculator 4.

The coefficient generator 5 can be formed of logic circuits as is the selector 11.

The matrix calculator 4 receives the hue data r, g and b from the hue data calculator 2, the polynomial data T2, T4 and T5 from the polynomial calculator 3 and the coefficients U from the coefficient generator 5, and outputs the results of calculation according to the following formula (1) as image data R1, G1 and B1.

$$\begin{bmatrix} R1 \\ G1 \\ B1 \end{bmatrix} = (Eij) \begin{bmatrix} r \\ g \\ b \end{bmatrix} + (Fij) \begin{bmatrix} T2 \\ T4 \\ T5 \end{bmatrix} \qquad \ldots (1)$$

In the formula (1), for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 3.

Fig. 8, which is a block diagram, shows an example of configuration of part of the matrix calculator 4. Specifically, it shows how R1 is calculated and outputted. As shown in Fig. 8, the matrix calculator 4 includes multipliers 12a, 12c, 12e and 12f, and adders 13a, 13d and 13e interconnected as illustrated.

Next, the operation of the matrix calculator 4 of Fig. 8 will be described. The multipliers 12a, 12c, 12e and 12f receive the hue data r, the polynomial data T2, T4 and T5 from the polynomial calculator 3 and the coefficients U(Eij) and U(Fij) from the coefficient generator 5, and then output the products thereof. The adder 13a receives the products outputted from the multipliers 12c and 12e, adds the inputted data and outputs the sum thereof. The adder 13d adds the output from the adder 13a and the product outputted from the multiplier 12f. The adder 13e adds the output from the adder 13d and the output (product) from the multiplier 12a, and outputs the sum total thereof as image data R1. In the example of configuration shown in Fig. 8, if the hue data r is replaced by the hue data g or b, and coefficients suitable for the respective terms (data) T2, T4 and T5 are used in substitution, image data G1 or B1 can be calculated.

Where it is desired to increase the calculation speed of the color converter 32, since parts of the coefficients (Eij) and (Fij) which respectively correspond to the hue data r, g and b are used, the configurations each as shown in Fig. 8 may be used in parallel, so as to perform the matrix calculation at a higher speed.

The synthesizer 6 receives the image data R1, G1 and B1 from the matrix calculator 4 and the minimum value α outputted from the minimum and maximum calculator 1 representing the achromatic data, performs addition, and outputs image data Ro, Go and Bo. The equation used for obtaining the image data color-converted by the color-

conversion method of Fig. 4 is therefore given by the following formula (2).

$$\begin{bmatrix} Ro \\ Go \\ Bo \end{bmatrix} = (Eij) \begin{bmatrix} r \\ g \\ b \end{bmatrix} + (Fij) \begin{bmatrix} h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \end{bmatrix} + \begin{bmatrix} \alpha \\ \alpha \\ \alpha \end{bmatrix} \qquad \ldots(2)$$

Here, for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 12, and

h1r = min (m, y),

h1g = min (y, c),

h1b = min (c, m),

h1c = min (g, b),

h1m = min (b, r),

h1y = min (r, g),

h2ry = min (aq1*h1y, ap1*h1r),

h2rm = min (aq2*h1m, ap2*h1r),

h2gy = min (aq3*h1y, ap3*h1g),

h2gc = min (aq4*h1c, ap4*h1g),

h2bm = min (aq5*h1m, ap5*h1b), and

h2bc = min (aq6*h1c, ap6*h1b),

and aq1 to aq6 and ap1 to ap6 indicate calculation coefficients selected by the calculation coefficient selector 11 of Fig. 5.

The difference between the number of calculation terms in the formula (2) and the number of calculation terms in Fig. 4 is that Fig. 4 shows a method of calculation for each pixel excluding the calculation terms which are of a value zero, while the formula (2) represents a general formula for

a set of pixels. In other words, twelve polynomial data for one pixel of the formula (2) can be reduced to three effective data, and this reduction is achieved by exploiting a characteristic of the hue data.

The combination of effective data is changed according to image data of the target pixel. For all image data, all the polynomial data can be effective.

Fig. 9A to Fig. 9F schematically show relations between the six hues (red, yellow, green, cyan, blue, magenta) and the hue data y, m, c, r, g and b. Each hue data relates to, i.e., extends to cover the range of three hues. For example, y as shown in Fig. 9A relates to, or extends to cover three hues of red, yellow and green.

Each of the foregoing formulae (1) and (2) includes a first comparison-result data effective only for one hue. The first comparison-result data are:

h1r = min (y, m),
h1y = min (r, g),
h1g = min (c, y),
h1c = min (g, b),
h1b = min (m, c), and
h1m = min (b, r).

Fig. 10A to Fig. 10F schematically show relations between the six hues and first comparison-result data h1r, h1y,h1g, h1c, h1b, and h1m. It is seen that each of the first comparison-result data relates to only one specific hue.

For instance, if W is a constant, for red, r = W, g = b = 0, so that y = m = W, and c = 0. The other five first comparison-result data are all of a value zero. That is, for red, h1r = min (y, m) alone is the only effective first comparison-result data. Similarly, h1g = min (c, y) is the only effective first comparison-result data for green; h1b = min (m, c) for blue; h1c = min (g, b) for cyan; h1m = min

(b, r) for magenta; and h1y = min (r, g) for yellow.

Fig. 11A to Fig. 11F schematically show relations between the six hues and second comparison-result data:

h2ry = min (h1y, h1r),
h2gy = min (h1y, h1g),
h2gc = min (h1c, h1g),
h2bc = min (h1c, h1b),
h2bm = min (h1m, h1b), and
h2rm = min (h1m, h1r).

This is the case in which the coefficients aq1 to aq6 and ap1 to ap6 in

h2ry = min (aq1*h1y, ap1*h1r),
h2rm = min (aq2*h1m, ap2*h1r),
h2gy = min (aq3*h1y, ap3*h1g),
h2gc = min (aq4*h1c, ap4*h1g),
h2bm = min (aq5*h1m, ap5*h1b), and
h2bc = min (aq6*h1c, ap6*h1b),

in the formula (1) above are all of a value "1".

It can be understood from Fig. 11A to Fig. 11F, that each of the second comparison-result data relates to changes in the six inter-hue areas of red-green, yellow-green, green-cyan, cyan-blue, blue-magenta, and magenta-red. In other words, for red-yellow, b = c = 0, and the five terms other than h2ry = min (h1y, h1r) = min (min (r, g), min (y, m)) are all zero.

Accordingly, only h2ry is an effective second comparison-result data for red-yellow. Similarly, only h2gy is an effective second comparison-result data for yellow-green; h2gc for green-cyan; h2bc for cyan-blue; h2bm for blue-magenta; and h2rm for magenta-red.

Fig. 12A to Fig. 12F schematically show how the range of the six inter-hue area to which each of the second comparison-result data relate is changed when the coefficients aq1 to aq6 and ap1 to ap6 used for

determination of h2ry, h2rm, h2gy, h2gc, h2bm and h2bc according to the foregoing formulae (6) and (1) are changed. The broken lines a1 to a6 shows the characteristics when aq1 to aq6 assume values larger than ap1 to ap6. The broken lines b1 to b6 shows the characteristics when ap1 to ap6 assume values larger than aq1 to aq6.

Specifically, for inter-hue area red-yellow, only h2ry = min (aq1*h1y, ap1*h1r) is an effective second comparison-result data. If, for example, the ratio between aq1 and ap1 is 2:1, the peak value of the second comparison-result data is shifted toward red, as indicated by the broken line a1 in Fig. 12A, and thus it can be made an effective comparison-result data for an area closer to red in the inter-hue area of red-yellow. On the other hand, for example if the ratio between aq1 and ap1 is 1:2, the relationship is like that indicated by the broken line b1 in Fig. 12A, the peak value of the second comparison-result data is shifted toward yellow, and thus it can be made an effective comparison-result data for an area closer to yellow in the inter-hue area of red-yellow. Similarly, by respectively changing:
aq3 and ap3 in h2gy for yellow-green,
aq4 and ap4 in h2gc for green-cyan,
aq6 and ap6 in h2bc for cyan-blue,
aq5 and ap5 in h2bm for blue-magenta and
aq2 and ap2 in h2rm for magenta-red,
the area for which each second comparison-result data is most effective can be changed.

Fig. 13A and Fig. 13B respectively show relations between the six hues and inter-hue areas and effective calculation terms. Thus, if the coefficients from among the conversion characteristics data, i.e., the calculation coefficients from the conversion characteristics storage 35, which are for a calculation term effective for a hue or an inter-hue area to be adjusted are changed, only the target

hue or inter-hue area can be adjusted.

Further, if coefficients selected by the calculation coefficient selector 11 in the polynomial calculator 3 are changed, part of the inter-hue area where a calculation term in the inter-hue area is most effective can be changed without giving any influence to the other hues.

When the color converter 32 is configured as described above, the conversion characteristics storage 35 stores the conversion characteristics data as the calculation coefficients. Fig. 14 is a block diagram showing an example of configuration of the conversion characteristics setting means 36. In Fig. 14, reference numeral 44 denotes a conversion characteristics calculator, and 45 denotes a conversion characteristics writing means 45. The conversion characteristics designation data from the conversion characteristics designation means 37 are inputted to the conversion characteristics calculator 44. The conversion characteristics calculator 44 calculates the conversion characteristics data in accordance with the inputted conversion characteristics designation data. The conversion characteristics data outputted from the conversion characteristics calculator 44 are written into the conversion characteristics storage 35 by means of the conversion characteristics writing means 45.

The color converter 32 uses calculation terms each of which is effective for just one of the six hues or just one of the six inter-hue areas. If the coefficient for the calculation term that is effective just for a hue or inter-hue area that is to be adjusted, the particular hue of inter-hue area can be adjusted, without affecting the activities of others. The conversion characteristics calculator 44 calculates the coefficients for each of the calculation term effective for the hue or inter-hue area for which the conversion characteristics has been designated, in

accordance with the contents or values of the conversion characteristics designation data from the conversion characteristics designation means 37.

For instance, if it is designated that chroma of red is to be multiplied by "1.1," the coefficients for the first comparison-result data h1r effective for red are newly calculated. The coefficients for h1r includes a coefficient for calculating R1, a coefficient for calculating G1 and a coefficient for calculating B1. If the chroma of red is set to be multiplied by "1.1," the coefficients for h1r can be calculated in the following manner. That is, the value corresponding to the value of the red designation data, of the conversion characteristics designation data shown in Fig. 3, is added to the coefficient for calculating R1, of the coefficients for h1r, and the value corresponding to the value of the red designation data is also added to the coefficient for calculating G1 or B1.

As an alternative, the value corresponding to the red designation data may be subtracted from the coefficient for calculating G1 or B1, of the coefficients for h1r.

When the conversion characteristics designation means 37 has the menu as shown in Fig. 2, and the color converter 32 is of the configuration shown in Fig. 4, the conversion characteristics calculator 44 newly calculates the coefficients for h1r responsive to designation by means of red chroma adjustment bar 38, the coefficients for h1y responsive to designation by means of yellow chroma adjustment bar 39, the coefficients for h1g responsive to designation by means of green chroma adjustment bar 40, the coefficients for h1c responsive to designation by means of cyan chroma adjustment bar 41, the coefficients for h1b responsive to designation by means of blue chroma adjustment bar 42, and the coefficients for h1m responsive to designation by means of magenta chroma adjustment bar 43.

As described above, if the colors for which the conversion characteristics can be designated by the conversion characteristics designation means 37 and the hues which can be independently adjusted by the color converter 32 are identical, then the calculation of the conversion characteristics data is easy.

The coefficients for the second comparison-result data h2ry, h2gy, h2gc, h2bc, h2bm, and h2rm can be determined on the basis of the coefficients for the first comparison-result data. As an alternative, the coefficients for the second comparison-result data can be calculated directly from the conversion characteristics data. The conversion characteristics designation means 37 newly calculates the values of these coefficients as required.

In Embodiment 1, the color converter 32 is of such a configuration that performs matrix calculation using the first and second comparison-result data. The color converter may be of a different configuration. The conversion characteristics storage may be a random access memory, so-called registers, or any other device in which the desired values can be set. The image data input circuit 31 and the image output means 33 are not indispensable, and may be omitted when input image processing or output image processing is not required.

As has been described, an image display device can be obtained by which it is possible to adjust the chroma of the color which it is desired to adjust,
by allowing a user to designate the conversion characteristics of the color which is to be adjusted by means of the conversion characteristics designation means.

Moreover, the color converter can be configured of hardware. Accordingly, an image display device can be obtained which can operate on a real-time basis responsive to moving pictures, without placing an excessive load on a

CPU.

Furthermore, the image data obtained after the color conversion can be sent to the image display unit via the image data output circuit, so that the image after the adjustment can be displayed on a real-time basis, with a size equal to the original image (image before the adjustment).

Embodiment 2

Fig. 15 is a block diagram showing an example of configuration of a conversion characteristics setting means 36 of Embodiment 2. In the drawing, reference numerals 44 and 45 denote members identical to those shown in Fig. 14. Reference numeral 46 denotes an initial characteristics storage. In this embodiment, the conversion characteristics calculator 44 calculates the conversion characteristics data on the basis of initial characteristics data from the initial characteristics storage 46 as well as the conversion characteristics designation data from the conversion characteristics designation means 37. The rest of the configuration is identical to that of Embodiment 1.

As in Embodiment 1, the conversion characteristics data are stored as the calculation coefficients in the conversion characteristics storage 35. The conversion characteristics designation data from the conversion characteristics designation means 37 are inputted to the conversion characteristics calculator 44. Also supplied to the conversion characteristics calculator 44 are the initial characteristics data from the initial characteristics storage 46. Stored in the initial characteristics storage 46 are conversion characteristics data (initial or default conversion characteristics) which are used when the user does not designate any conversion characteristics. The conversion characteristics calculator 44 changes the value of the initial characteristics data according to the

inputted conversion characteristics designation data, and outputs the result of the change as the conversion characteristics data. When the conversion characteristics designation data indicates that the user does not designate the conversion characteristics, then the value of the initial characteristics data are used as the conversion characteristics data.

For instance, if it is designated that the chroma of red is to be multiplied by "1.1," the coefficient for the first comparison-result data h1r effective for red is newly calculated. The coefficients for h1r includes a coefficient for calculating R1, a coefficient for calculating G1 and a coefficient for calculating B1. If the multiplication factor of the chroma of red is set to be "1.1," the coefficients for h1r can be calculated in the following manner. That is, a value corresponding to the value of the red designation data, of the conversion characteristics designation data shown in Fig. 3, is added to the coefficient for calculating R1, of the coefficients for h1r, and the value corresponding to the value of the red designation data is also added to the coefficient for calculating G1 or B1.

As an alternative, the value corresponding to the red designation data may be subtracted from the coefficient for calculating G1 or B1, of the coefficients for h1r.

Conversion characteristics data for correcting the color reproduction characteristics inherent to the image display unit 34 may be stored as the initial characteristics data. The user may designate the conversion characteristics depending on the user's preference and/or visual environment in which the conversion characteristics setting means is used, starting from the initial values. The initial characteristics storage may be formed of a random access memory, or so-called registers, or any other device that can

store desired values. The initial characteristics storage may be of such a configuration that allows the initial characteristics data to be written from the outside.

As has been described, an image display device can be obtained by which it is possible to adjust the chroma of the color which it is desired to adjust, starting from the initial characteristics stored in advance, by allowing a user to designate the conversion characteristics of the color which is to be adjusted by means of the conversion characteristics designation means.

Moreover, the color converter can be configured of hardware. Accordingly, an image display device can be obtained which can operate on a real-time basis responsive to moving pictures, without placing an excessive load on a CPU.

Furthermore, the image data obtained after the color conversion can be sent to the image display unit via the image data output circuit, so that the image after the adjustment can be displayed on a real-time basis, with a size equal to the original image (image before the adjustment).

Embodiment 3

Fig. 16 shows an example of menu displayed on the screen of the image display unit 34 in Embodiment 3. In Fig. 16, reference numeral 38 denotes a red chroma adjustment bar, 40 denotes a green chroma adjustment bar, and 42 denotes a blue chroma adjustment bar. They are identical to those of Embodiment 1 shown in Fig. 2. In Embodiment 1, the user designates the conversion characteristics using the chroma adjustment bars for six colors of red, yellow, green, cyan, blue and magenta. In this embodiment, the user designates the conversion characteristics using chroma adjustment bars for three colors of red, green and blue. Thus, the designation of

conversion characteristics is simpler. The rest of the configuration is identical to that of Embodiment 1.

The user selects one of the red chroma adjustment bar 38, green chroma adjustment bar 40 and blue chroma adjustment bar 42 that corresponds to the color for which the chroma is to be adjusted, i.e., the conversion characteristics is to be changed. The selected chroma adjustment bar lets the user know that it has been selected, by varying its hue or brightness. When the selection of the desired chroma adjustment bar is completed, the user then designates the chroma of the selected color. The designation of the chroma is performed by designating the ratio of the chroma of each of the colors represented by the three color data Ro, Go and Bo (second set of color data) outputted from the color converter 32, with respect to the chroma of each of the colors represented by the three color data Ri, Gi and Bi (first set of color data) inputted to the color converter. By repeating the above-described operation, the user can designate the desired color conversion characteristics.

In the example of Fig. 16, the designated conversion characteristics is such that the chroma of red is to be multiplied by "1.1," and the chroma of green is to be multiplied by "1.0" and the chroma of blue is to be multiplied "1.0."

The conversion characteristics designation means 37 generates the conversion characteristics designation data in accordance with the values of the red chroma adjustment bar 38, green chroma adjustment bar 40 and blue chroma adjustment bar 42. Fig. 17 shows an example of configuration of the conversion characteristics designation data. In the example shown in Fig. 17, the conversion characteristics designation data comprises red designation data (RED D. D.), green designation data (GREEN D. D.), and

blue designation data (BLUE D. D.) which are arranged in the stated order. The value of each of the designation data is the ratio of the chroma of each of the colors represented by Ro, Go and Bo to the chroma of each of the colors represented by Ri, Gi and Bi, which has been designated by the user by the use of the chroma adjustment bar. With respect to the colors that are not adjusted by the user, the value of each designation data is "1.0." When the designation is as shown in Fig. 16, the value of he red designation data is "1.1," the value of the green designation data is "1.0," and the value of the blue designation data is "1.0."

As in Embodiment 1, the conversion characteristics designation data from the conversion characteristics designation means 37 are inputted to the conversion characteristics calculator 44. The conversion characteristics calculator 44 newly calculates and outputs the conversion characteristics data in accordance with the inputted conversion characteristics designation data.

For instance, if it is designated that chroma of red is to be multiplied by "1.1," the coefficient for the first comparison-result data h1r effective for red is newly calculated. The coefficients for h1r includes a coefficient for calculating R1, a coefficient for calculating G1 and a coefficient for calculating B1. If the chroma of red is set to "1.1," the coefficients for h1r can be calculated in the following manner. That is, the value corresponding to the value of the red designation data, of the conversion characteristics designation data shown in Fig. 17, is added to the coefficient for calculating R1, of the coefficients for h1r, and the value corresponding to the value of the red designation data is also added to the coefficient for calculating G1 or B1.

As an alternative, the value corresponding to the red

designation data may be subtracted from the coefficient for calculating G1 or B1, of the coefficients for h1r.

Similarly, when the conversion characteristics of green are designated, the coefficients for the first comparison-result data h1g effective for green are newly calculated, and when the conversion characteristics of blue are designated, the coefficients for the first comparison-result data h1b effective for blue are newly calculated.

The coefficients for the first comparison-result data h1y, h1m and h1c, and the second comparison-result data h2ry, h2gy, h2gc, h2bc, h2bm, and h2rm can be determined on the basis of the coefficients for the first comparison-result data h1r, h1g and h1b effective for red, green and blue. As an alternative, the coefficients for h1y, h1m and h1c, and the second comparison-result data can be calculated directly from the conversion characteristics data. The conversion characteristics designation means 37 newly calculates the values of these coefficients as required.

As has been described, an image display device can be obtained by which it is possible to adjust the chroma of the color which it is desired to adjust, by allowing a user to designate the conversion characteristics of the color which is to be adjusted by means of the conversion characteristics designation means.

Moreover, the color converter can be configured of hardware. Accordingly, an image display device can be obtained which can operate on a real-time basis responsive to moving pictures, without placing an excessive load on a CPU.

Furthermore, the image data obtained after the color conversion, can be sent to the image display unit via the image data output circuit, so that the image after the adjustment can be displayed on a real-time basis, with a size equal to the original image (image before the

adjustment).

In addition, since the conversion characteristics are designated from the three colors of red, green and blue, the adjustment is simple.

Embodiment 4

Fig. 18 shows an example of menu displayed on the screen of the image display unit 34 in Embodiment 4. In Fig. 18, reference numeral 47 denotes an all-color adjustment bar. In Embodiment 1, the user designates the conversion characteristics using the chroma adjustment bars for six colors of red, yellow, green, cyan, blue and magenta. In this embodiment, the user adjusts the chroma by means of the single chroma adjustment bar. The rest of the configuration is identical to that of Embodiment 1.

The conversion characteristics designation data from the conversion characteristics designation means 37 are inputted to the conversion characteristics setting means 36. In the conversion characteristics setting means 36, the conversion characteristics designation data from the conversion characteristics designation means 37 are inputted to the conversion characteristics calculator 44. The conversion characteristics calculator 44 newly calculates the conversion characteristics data in accordance with the inputted conversion characteristics designation data.

If the conversion characteristics designation means 37 has the menu shown in Fig. 18, and the color converter 32 is of the configuration shown in Fig. 4, the conversion characteristics calculator 44 newly calculates the coefficients for h1r, h1y, h1g, h1c, h1b and h1m, simultaneously, in response to the designation by means of the all-color adjustment bar.

The conversion characteristics data outputted from the conversion characteristics calculator 44 are inputted to the conversion characteristics writing means 45, which sets the

inputted conversion characteristics data in the conversion characteristics storage 35.

As has been described, an image display device can be obtained by which it is possible to adjust the chroma of the color which it is desired to adjust,
by allowing a user to designate the conversion characteristics of the color which is to be adjusted by means of the conversion characteristics designation means.

Moreover, the color converter can be configured of hardware. Accordingly, an image display device can be obtained which can operate on a real-time basis responsive to moving pictures, without placing an excessive load on a CPU.

Furthermore, the image data obtained after the color conversion, can be sent to the image display unit via the image data output circuit, so that the image after the adjustment can be displayed on a real-time basis, with a size equal to the original image (image before the adjustment).

In addition, since the conversion characteristics are designated simultaneously for all colors, the adjustment is simple.